Metrics and Valuation Framework for System Planning and Proposed Investments

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Distribution Systems and Planning Training
For Midwest Public Utility Commissions, January 16-17, 2018

PNNL-SA-129312

GMLC 1.1: Metrics Analysis

High Level Summary

Project Objectives

Work directly with *strategic* stakeholders to confirm the usefulness of *new and enhanced existing* metrics that will guide grid modernization efforts to maintain and improve:

- **Reliability,**
- **Resilience,**
- **Flexibility,**
- **Sustainability,**
- **Affordability, and**
- **Security.**

Expected Outcomes

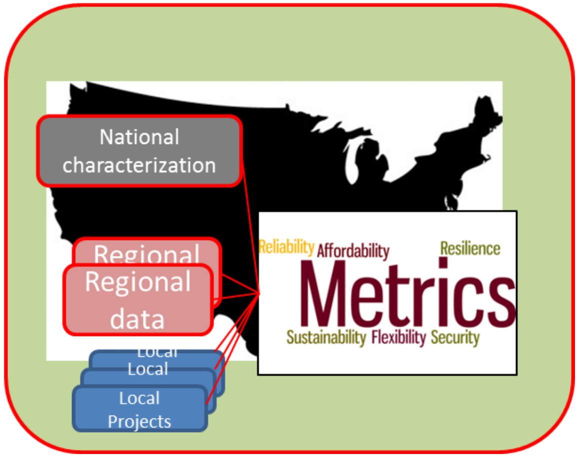
✓ Definition, Validation, and Adoption of metrics and analysis approaches by leading industry stakeholders and regional partners

✓ Better alignment of DOE R&D priorities with stakeholder and public-interest objectives

Value Proposition

✓ Ensuring that all stakeholders understand how grid modernization investments will affect and benefit them

✓ Audiences: grid modernization technology developers and investors; utility and ISO technology adopters or sponsors; federal, state, and municipal regulatory or oversight authorities; **and electricity consumers** (i.e., the ratepayers)



GMLC 1.1: Metrics Analysis
Accomplishments to Date

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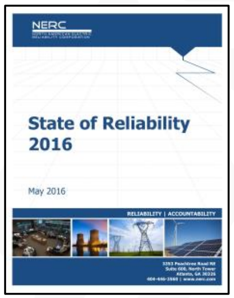
Reliability

Lead: Joe Eto (LBNL)

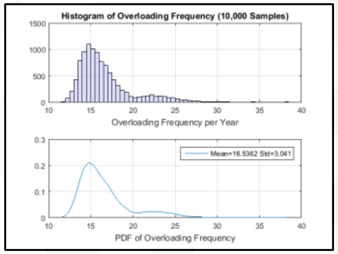
<u>Value:</u> new metrics for reliability value-based planning and bulk power system assessment

New metrics for distribution that capture the economic cost of interruptions to customers



New metrics for system impacts using North American Electric Reliability Corporation transmission/generation availability data

Approach and tool for and demonstration of probabilistic enhancement of existing transmission planning metrics



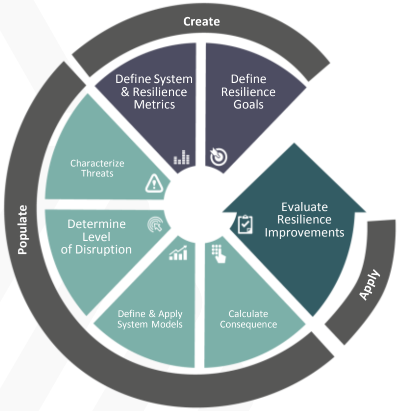
<u>Next steps</u>: new metrics/processes for:
- NERC State of Reliability report
- transmission planning

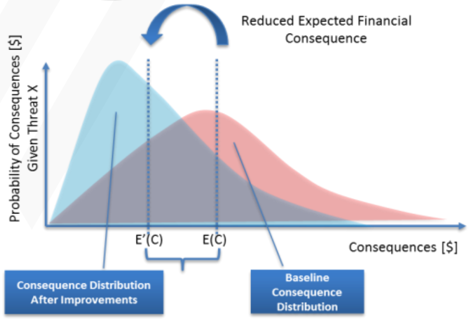
Resilience

Lead: Eric Vugrin (SNL)

<u>Value:</u> create new metrics/process for resilience investm.

Analysis Process





Results

<u>Next steps</u>: Validate with New Orleans

GMLC 1.1: Metrics Analysis

Accomplishments to Date

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Flexibility

Lead: Tom Edmunds(LLNL)

Value: Develop and demonstrate usefulness of new flexibility metrics

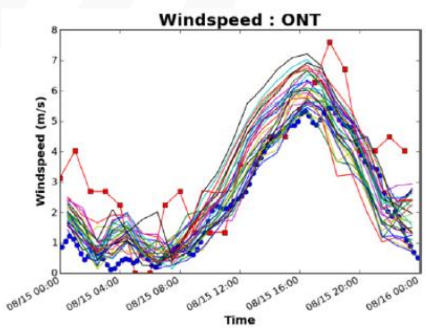
Developed large set of candidate metrics that represent network properties of flexibility and lack of flexibility, engaging stakeholders to identify most useful metrics

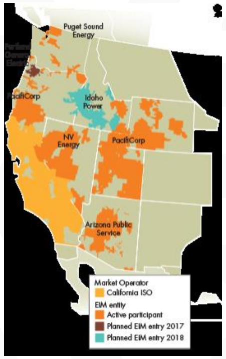
Lagging indicators

- Requires statistical analysis of market and grid conditions to reveal curtailments, loss of load, or other economic impacts caused by insufficient flexibility.

Leading indicators

- Requires production cost simulations with weather and other uncertainties to design for sufficient flexibility.
- Use production cost models to examine tradeoffs between different sources of flexibility.





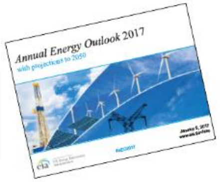
Next steps: Work with CAISO, ERCOT to adopt flexibility metrics

Sustainability

Lead: Garvin Heath (NREL)

Value: Identify needed improvements to GHG reporting

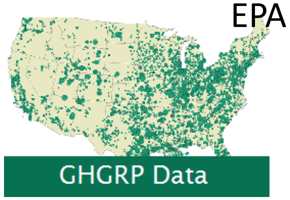
Ability of federal greenhouse gas data products to capture changes in electric-sector CO_2 emissions that might result from future grid modernization varies, depending on coverage of certain energy sources anticipated to grow.



EIA: AEO

EPA: eGRID

EIA: MER



EPA: GHGRP

Next steps: Assess usefulness and availability of data for impacts on water resources

GMLC 1.1: Metrics Analysis

Accomplishments to Date

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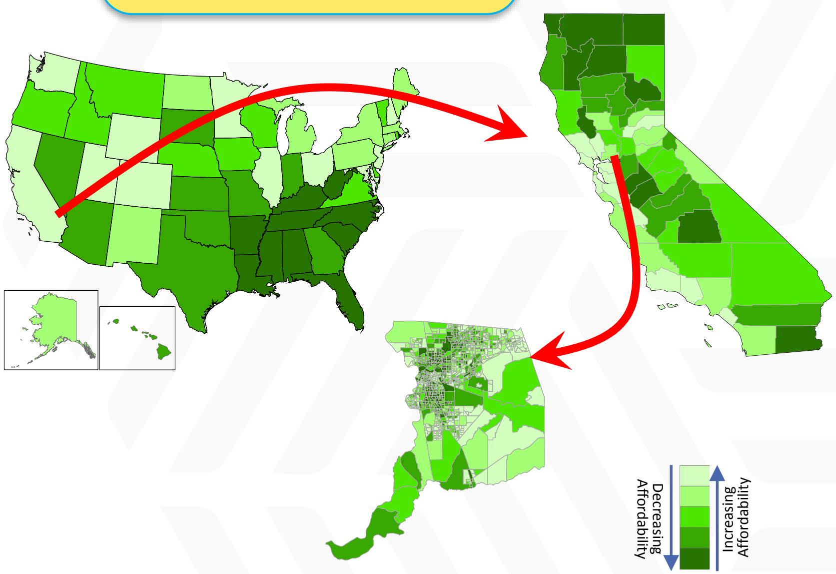
Affordability

Lead: Dave Anderson (PNNL)

Value: Establish new metrics based on cost burden to consumers

Cost Burden Metrics (**emerging**)

- Customer electricity cost burden
- Electricity affordability gap
- Affordability gap headcount
- Temporal indices of these metrics



Next steps: Validating metrics with Regional Partners (Alaska, New Orleans)

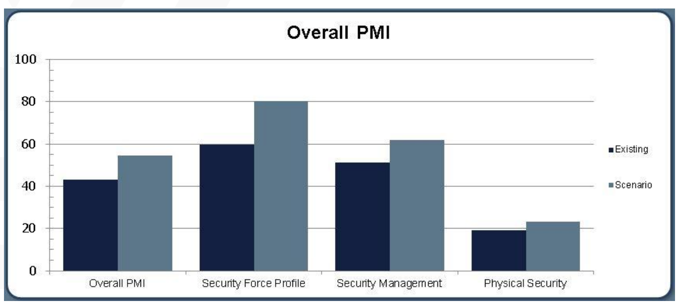
Security

Lead: Steve Folga (ANL)

Value: Spur electric industry adoption of DHS Protective Measures Indices (i.e., security metrics)

Survey/analysis Process

Results



Next steps: Validate PMI Approach with ComED and Idaho Falls

Reliability

Distribution Reliability

Existing metrics	Existing (data needed)
SAIFI	Total customers served
SAIDI	
CAIDI	Customer interruption duration
CAIFI	
CTAIDI	
ASAI	Customer hours service availability
	Customer service hours demanded
MAIFI	Total customer momentary interruptions
CEMI	Total customers experiencing more than n sustained outages
CEMSMI	Total customers experiencing more than n momentary interruptions
CI	Customers interrupted
CMI	Customer minutes interrupted
ASIFI	Total connected kVA of load interrupted
ASIDI	Total connected kVA served
CELID	total number of customers that have experienced more than eight interruptions in a single reporting year
SARI	Circuit outage number and duration
COR	number of correct operations
	total number of operations commanded
DELI	total distribution equipment experiencing long outages
DEMI	length of interruption (by equipment type)
ACOD	Transmission circuit outage and duration
ACSI	
TACS	total amount of equipment that have more than N # of interruptions in a single year
FOHMY	Outages per hundred miles per year

Proposed Metrics	Proposed Data Needed
Interruption Cost	Customers interrupted (by type of customer)
	Characteristics of interruptions by customer type (e.g., duration, start time)

Landscape of Existing and Proposed Metrics
Resilience

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Resilience

Existing (metrics)	Existing (data needed)
Cost of recovery	
Utility revenue lost	outage cost for utility ($)
Cost of grid damage	total cost of equipment repair
Cost per outage	

Proposed Metrics	Proposed (data needed)
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	
Cost of recovery	
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided $ / kVA
Critical **COMMUNITY** services without power	number of critical services without power total number of critical services
Critical services without power after backup fails	total number of critical services with backup power duration of backup power for critical services
Loss of assets and perishables	
Business interruption costs	avg business losses per day (other than utility)
Impact on GMP or GRP	
Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

Interdependence of Metrics
Reliability and Resilience

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Distribution Reliability

Existing metrics	Existing (data needed)
SAIFI	Total customers served
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CAIDI	Customer interruption duration
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Resilience

Existing Metrics	Existing (data needed)
Cost of recovery	
Utility revenue lost	outage cost for utility ($)
Cost of grid damage	total cost of equipment repair
Cost per outage	

Proposed Metrics	Proposed (data needed)
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted (by customer?)
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served (by customer?)
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	Thresholds? What does recovery mean?
Cost of recovery	Same as above
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided
	$ / kVA
Critical services without power	number of critical services without power
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Critical services without power after backup fails	total number of critical services with backup power
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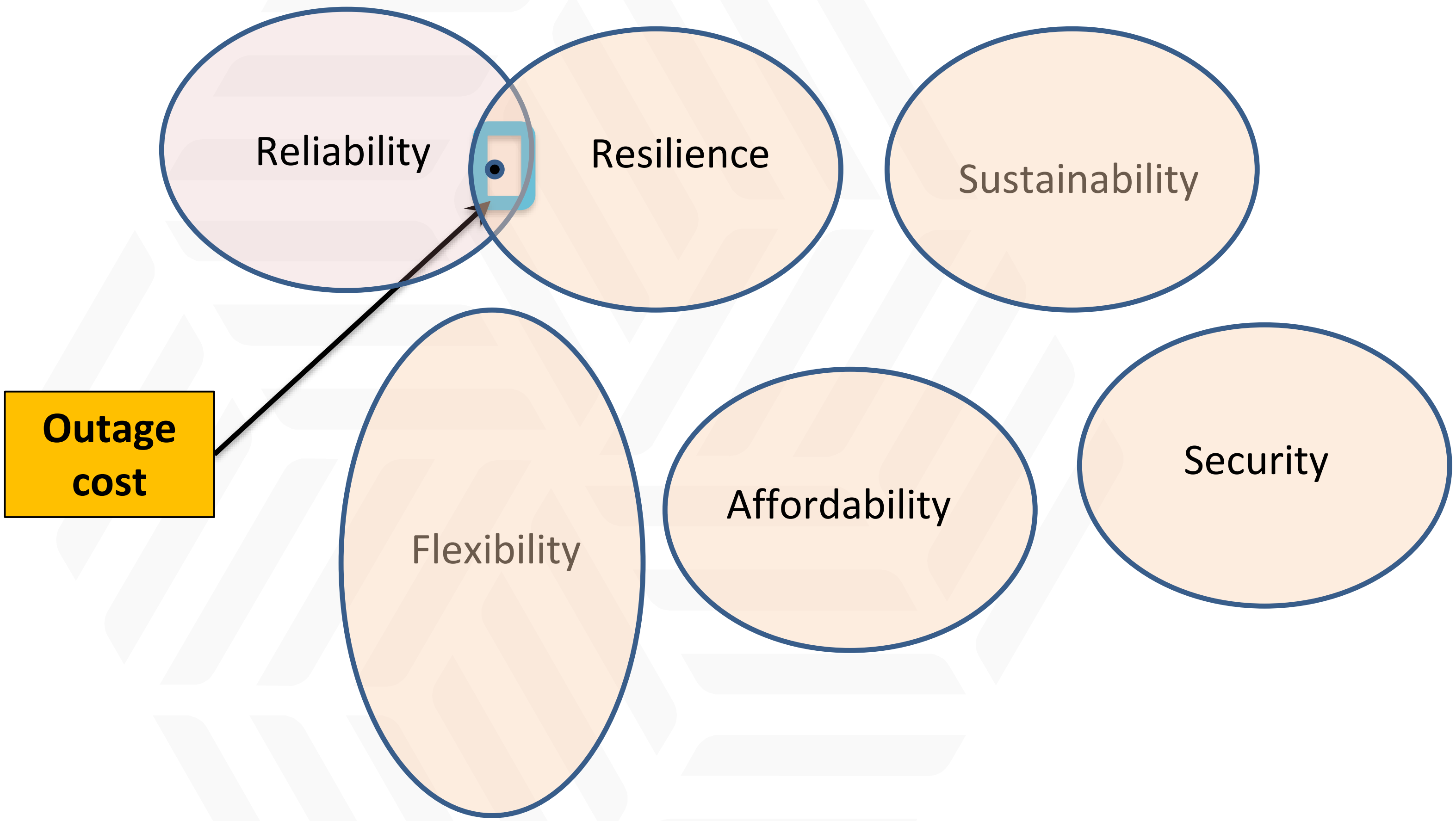
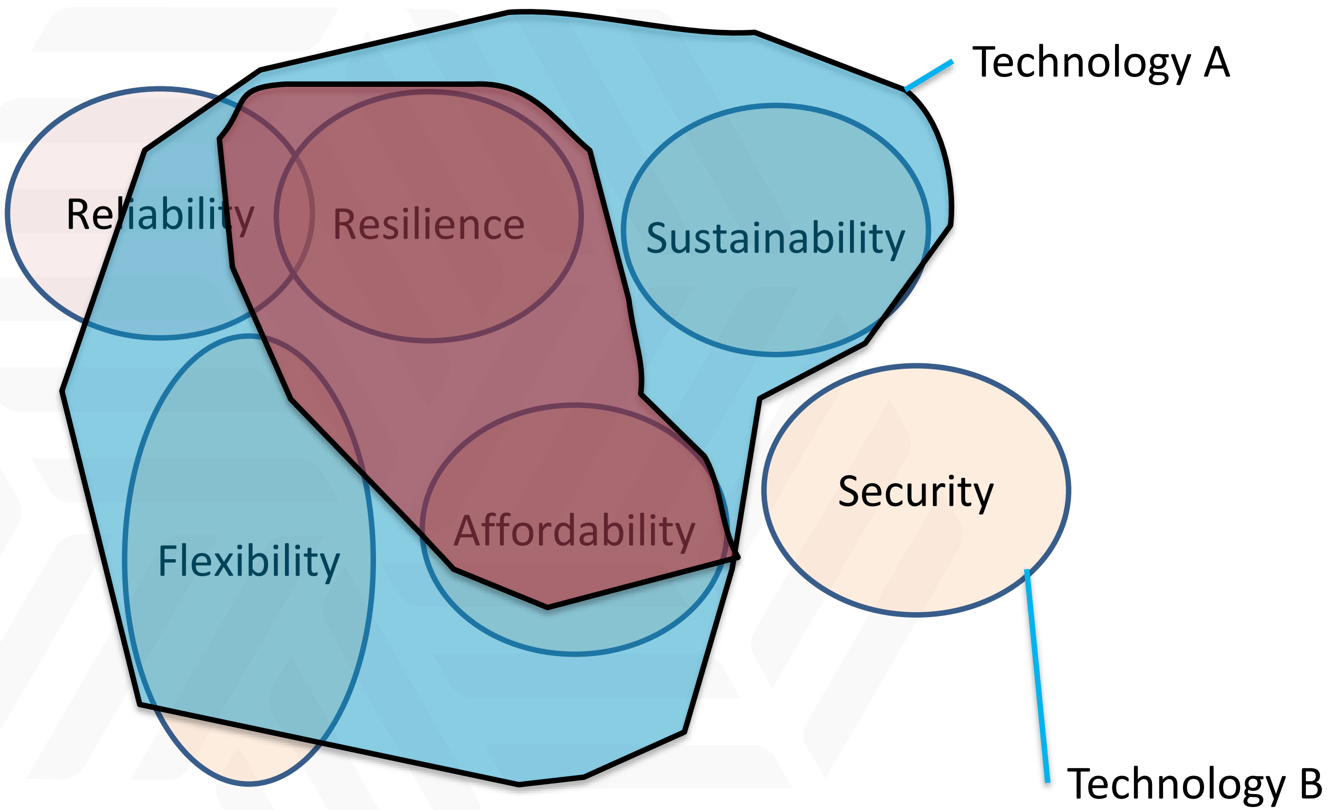
Interdependence of Metrics only between 2 Metrics Areas



Technologies Impact Several Metrics

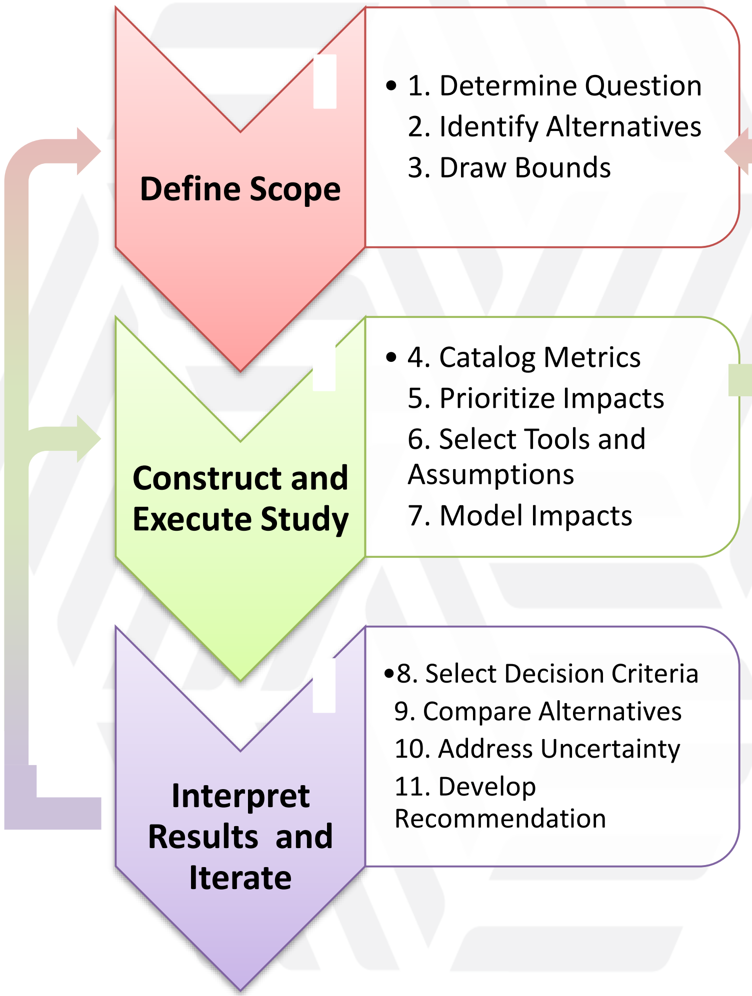


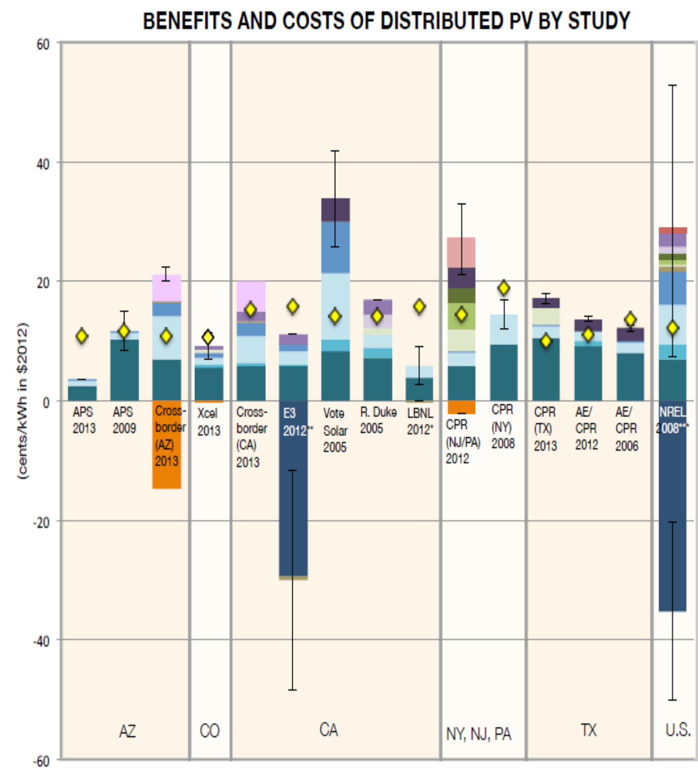
Synergy between Metrics and Valuation

- Metrics = the language by which one expresses changes in system operations and system states and their impacts to customers and the environment
- Valuation = estimating cost of a technology or policy <u>and</u> the monetary or non-monetary values of the changes (before and after deployment) and their impacts.
- Thus, with more refined and richer set of metrics, more precise and more comprehensive valuation can be performed.
- However, methods and tools need to be created to support valuation to project likely changes to the system and their impacts to customers and the environment.

Valuation Framework Development

The “Framework” is really a set of guidelines on how to move through a valuation as a process to reveal all assumptions and models used



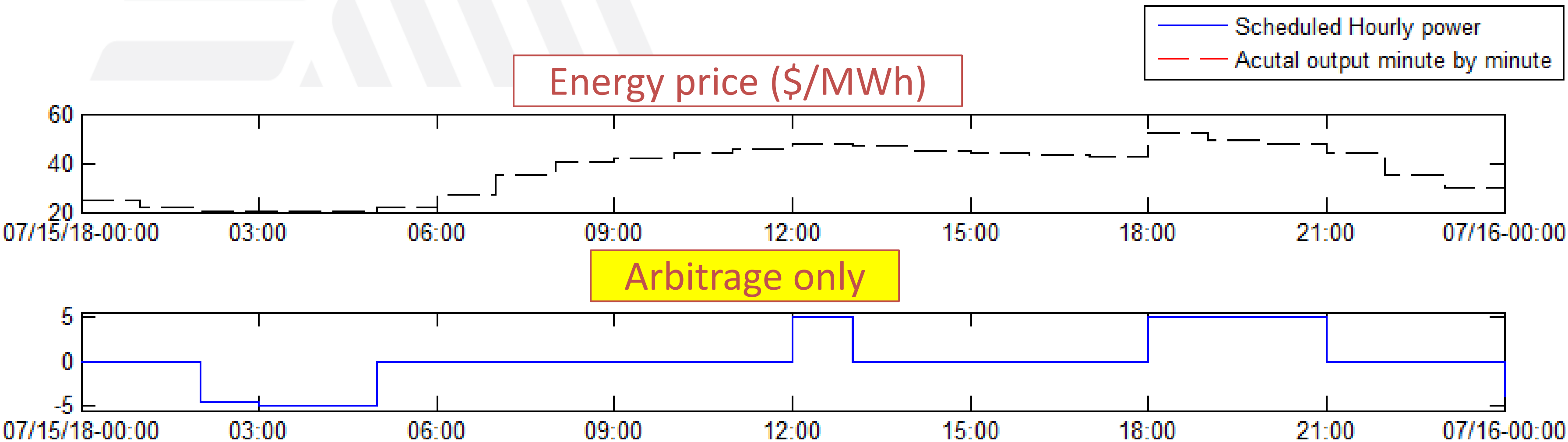


From RMI *“A review of solar PV benefit and cost studies”*

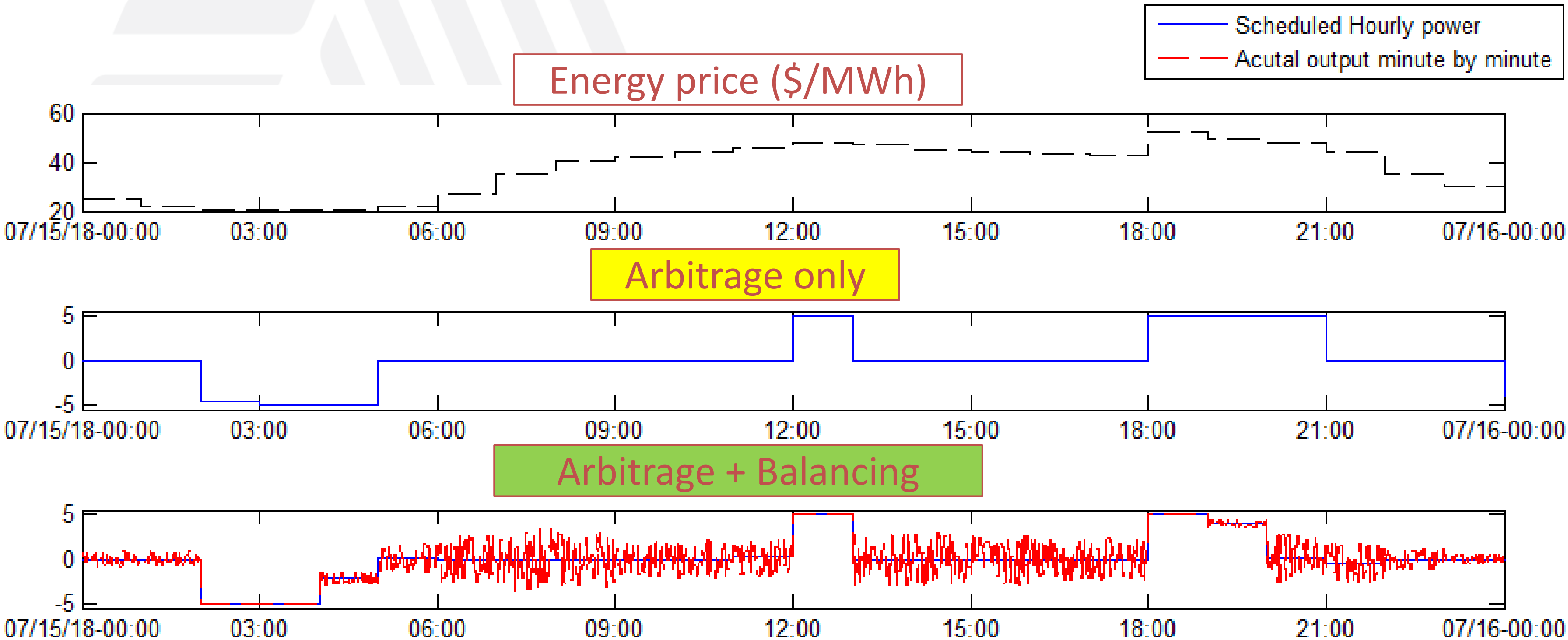
Example Valuation: Distributed Energy Storage

- ALL Storage provides flexibility most systems "desire/need" under growing renewable technology deployment
  - Question: Which location, which size, and how to control it
- Storage technology is expensive, thus requires to capture multiple values to be cost-effective.
  - Requires operational optimization ALL THE TIME
- What are the right business cases for storage?
  - How does performance and storage type matter?
  - How to value multiple benefits?

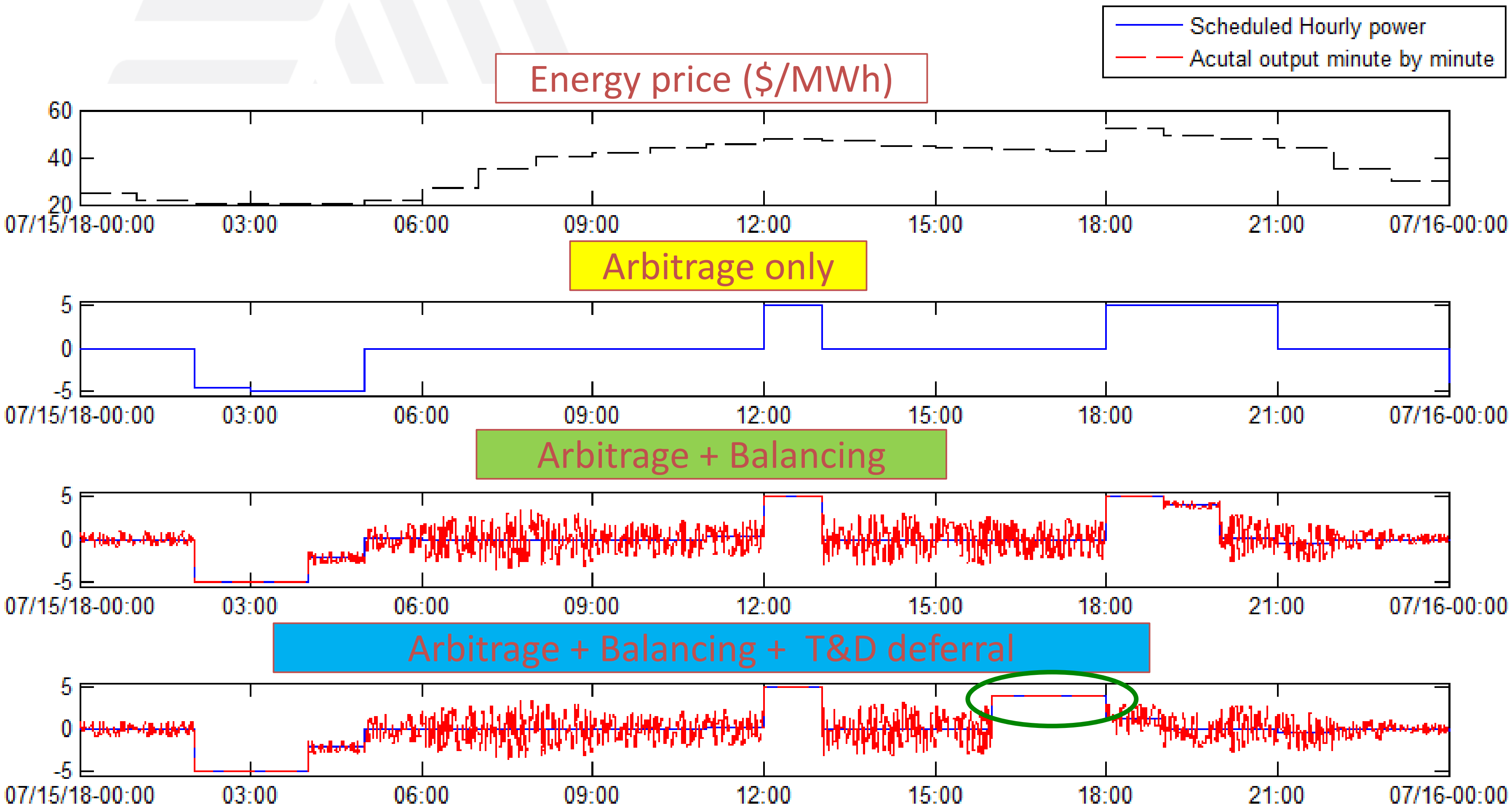
How to value multiple benefits?



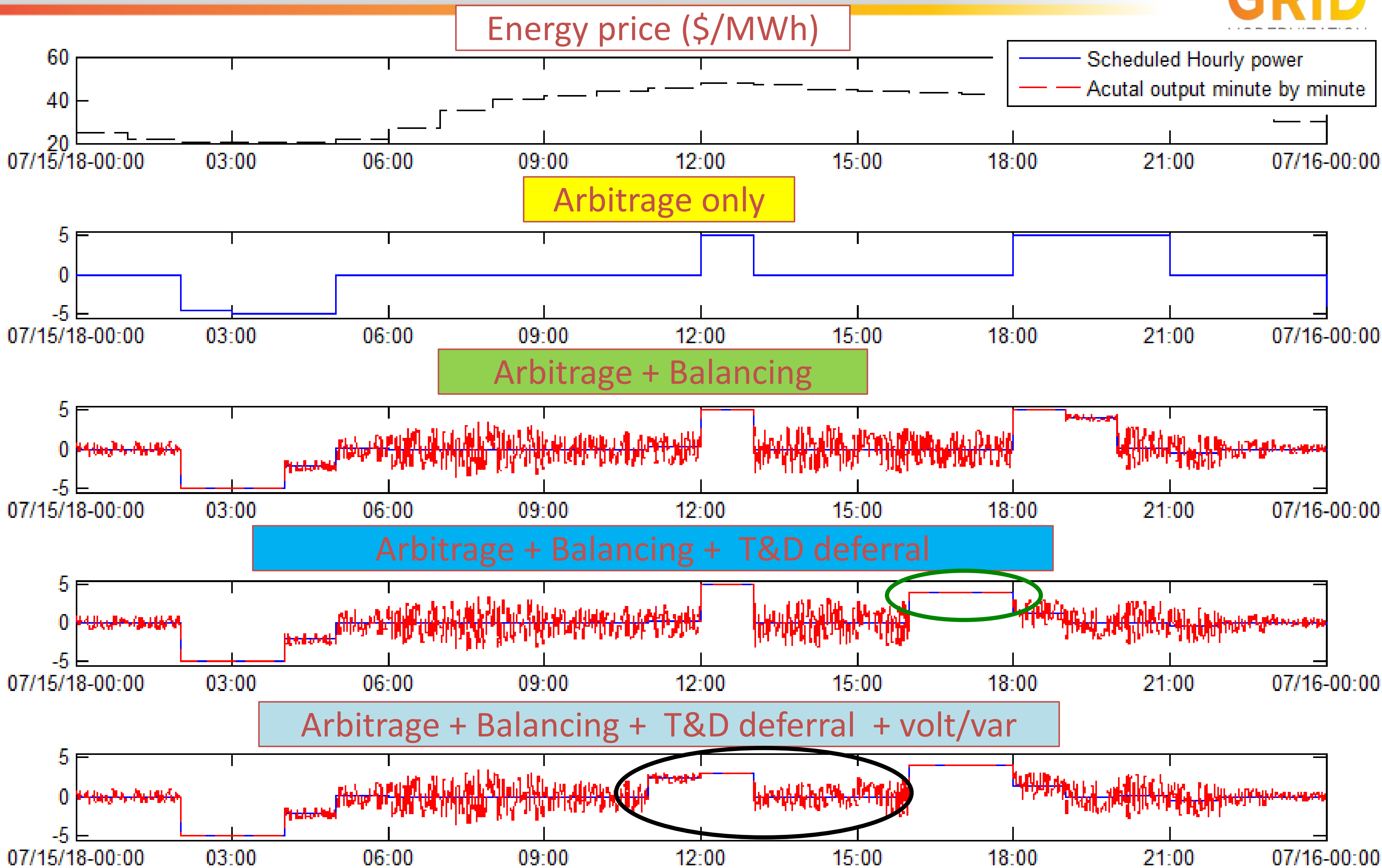
How to value multiple benefits?



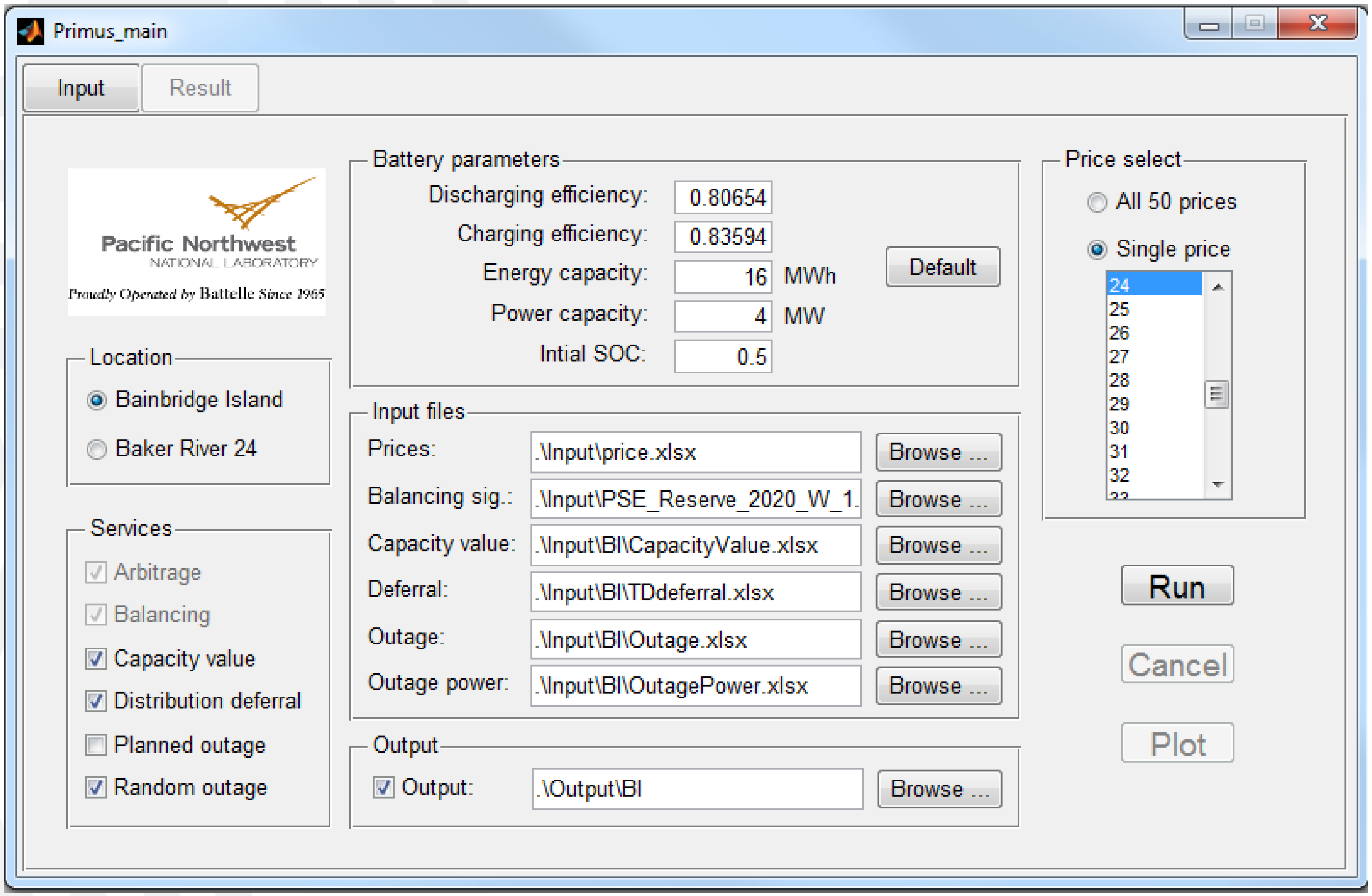
How to value multiple benefits?



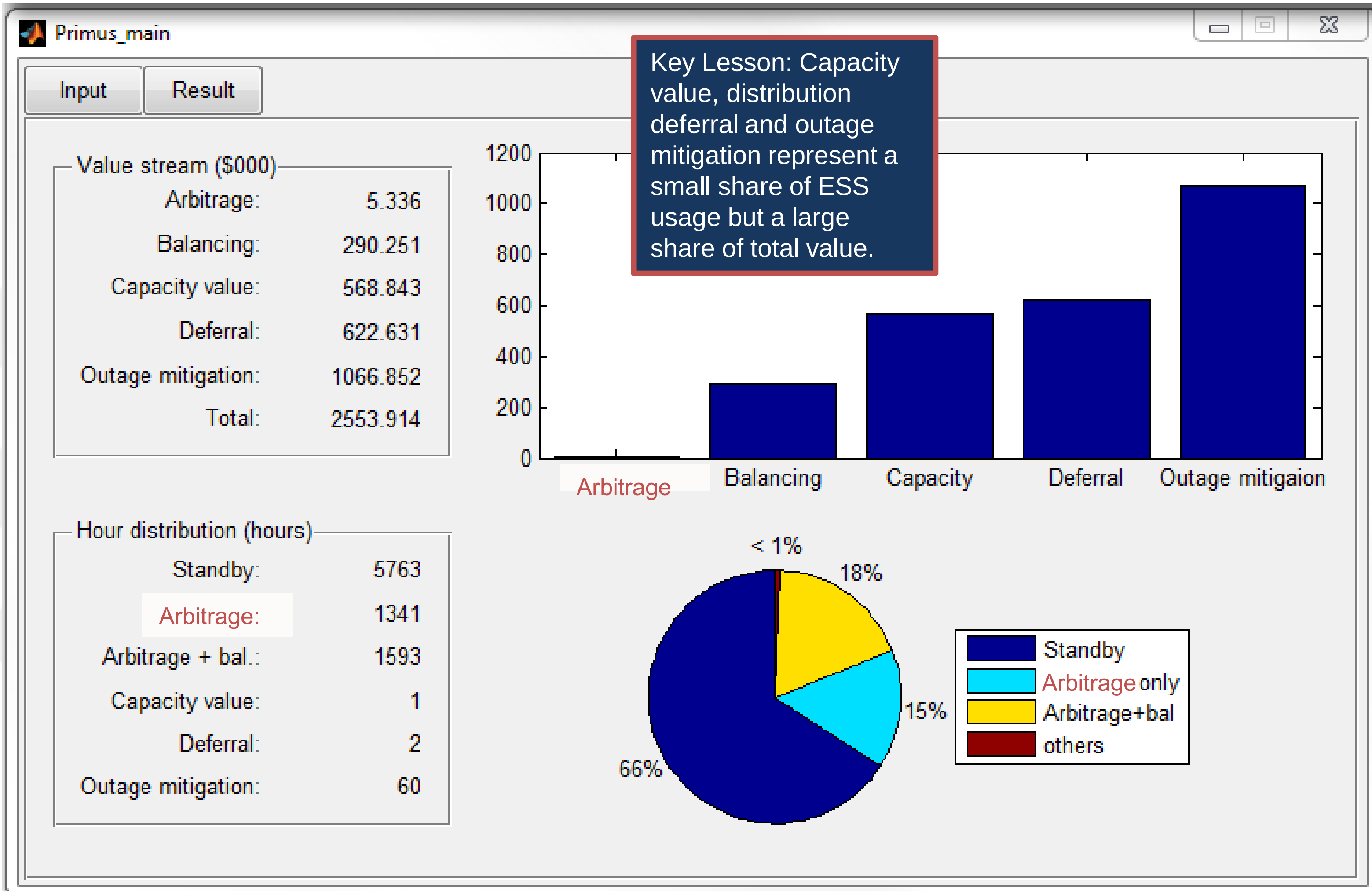
How to value multiple benefits?



Battery Storage Evaluation Tool (BSET) Graphical User Interface

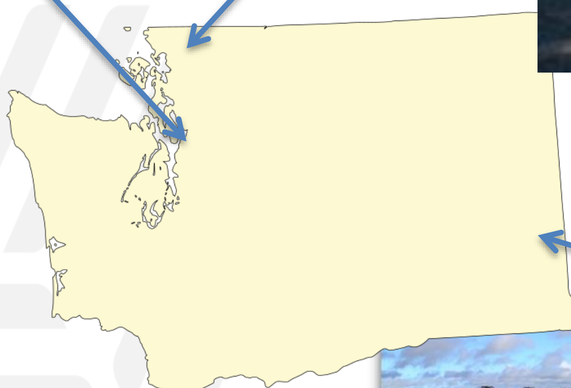


BSET Output



Key Lesson: Capacity value, distribution deferral and outage mitigation represent a small share of ESS usage but a large share of total value.

Washington State CEF Energy Storage Projects



2 MW / 4.4 MWh lithium-ion/phosphate battery – Glacier, WA

2MW / 1 MWh Li-ion system 2MW, 8.8 MWh UET vanadium-flow- Everett, WA

Total – 7 MW / 15 MWh; $14.3 million state investment / $43 million total investment for energy storage systems

1 MW / 3.2 MWh UET vanadium-flow battery – Pullman, WA

Washington CEF Matrix

Use Case and application as described in PNNL Catalog	Avista	PSE	Sno – MESA1	Sno – MESA2	Sno - Controls Integration
UC1: Energy Shifting					
Energy shifting from peak to off-peak on a daily basis	Y	Y	Y	Y	
System capacity to meet adequacy requirements	Y	Y	Y	Y	
UC2: Provide Grid Flexibility					
Regulation services	Y	Y		Y*	
Load following services	Y	Y		Y*	
Real-world flexibility operation	Y	Y		Y*	
UC3: Improving Distribution Systems Efficiency					
Volt/Var control with local and/or remote information	Y		Y	Y	
Load-shaping service	Y	Y	Y	Y	
Deferment of distribution system upgrade	Y	Y			
UC4: Outage Management of Critical Loads		Y			
UC5: Enhanced Voltage Control					
Volt/Var control with local and/or remote information and during enhanced CVR events	Y				
UC6: Grid-connected and islanded micro-grid operations					
Black Start operation	Y				
Micro-grid operation while grid-connected	Y				
Micro-grid operation in islanded mode	Y				
UC7: Optimal Utilization of Energy Storage	Y	Y			Y

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Summary of Best Practice for Storage Valuation

- Developing clear understanding of the function of storage. Function will drive valuation process
- In most cases, cost-effectiveness requires to estimate bundled values
- Bundling multiple services is challenging and requires optimization to make decisions which is the highest valued service to capture.
  - Valuation Trap:
    - Double counting of resources
    - Over-committing available resources
- Performance of storage technology matters in the valuation process
- Not all values of grid services are easily obtainable.
  - Market based values are preferred, however, don't help if value is to be estimated into the future
  - For non-market services, simulations and avoided cost estimation become necessary. This often requires a lot of modeling effort

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- General valuation methods:
  - New York: Staff White Paper on Benefit-Cost Analysis in the Reforming Energy Vision Proceeding: 14-M-0101 https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/c12c0a18f55877e785257e6f005d533e/$FILE/Staff_BCA_Whitepaper_Final.pdf
  - Rhode Island: Docket 4600: Stakeholder Working Group Process: http://www.ripuc.org/eventsactions/docket/4600page.html
  - California: SCE: Distribution Resource Plan. July 1, 2015: available at http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/BF42F886AA3F6EF088257E750069F7B7/$FILE/A.15-07-XXX_DRP%20Application-%20SCE%20Application%20and%20Distribution%20Resources%20Plan%20.pdf

Discussion on Resilience

Discussion on Resilience

- Definition of resilience:

  "The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents." Source: Presidential Policy Directive 21 [PPD-21, Obama 2013]

- Differentiations between resilience and reliability
  - RELIABILITY:
    - Lack of reliability causes short-term interruptions (minutes to hours)
    - Associated with design conditions during normal grid operations (blue sky operations)
  - RESILIENCE
    - Lack of resilience occurs during catastrophic events (**black sky scenarios**) with long-term interruptions to electric service customers and disruption to critical community services
    - Interruption durations longer than 24 hours

- FERC issued a new Order (January 8th, 2018)
  - In response to the Secretary Perry's Proposed Rule on Grid Reliability and Resilience Pricing
  - Order requires RTOs/ISOs within 60 days to address the following questions categories :
    - What is the RTO's/ISO's understanding of grid resilience ?
    - How do RTOs/ISOs assess threats to resilience ?
    - How do RTOs/ISOs mitigate threats to resilience ?
  - In the footnote (#31), the order encourages other entities to engage with State regulators to address resilience at the distribution level

Differentiation between Resilience and Reliability

Metrics Reliability

	Customer's perspective	Utility's perspective
SAIDI, SAIFI	Outage cost by customer	Lost revenue
CAIDI, CAIFI		Restauration cost
….		

LBNL's ICE calculator
Valid for reliability events
Up to 24 hours

Reliability event

Service interruption

Onset of interruption

1day

weeks

Timeline of interruption

Metrics Resilience

	Customer's perspective	Utility's perspective	Community's perspective
SAIDI, SAIFI	Outage cost by customer	Lost revenue	Critical community services disruption
CAIDI, CAIFI		Restauration cost	Economic disruptions with impacts on GRP
….			Large reconstruction cost

Service Interruption

Resilience event

- Direct impacts/consequence: Interruption cost. No data exist for multi-days interruptions. Notionally cost increasing more than linearly
- Indirect/induced impacts:
  - community disruptions (impact safety, health and wellbeing)
  - Economic disruption: that percolates through local/regional economy

Two Approaches toward Metrics Development for Resilience

- Approach 1: Consequence-based approach
  - Addresses the consequences of one or multiple threats to an asset or infrastructure
  - Applications: assess consequences (direct and indirect) of threats. And used for assessing mitigation strategies to explore change in consequences. It's usually associated with projections and modeling (leading indicators)
  - Purpose: Prioritizing investments for infrastructure hardening and mitigation strategies.
- Approach 2: Attribute-based approach
  - Addresses the survivability posture of an asset or infrastructure to a threat or the ability to recover from a threat, predicated on sets of attributes describing level of
    - Preparedness
    - Ability to resist and absorb
    - Ability to respond, adapt, and recover
  - Applications: Requires a detailed survey instrument to collect resilience attribute characteristics and an elicitation process to define their contribution to the overall resilience
  - Purpose:
    - Used for monitoring progress on the resilience posture
    - Enables comparability to peers and any other cohorts
- Synergies between Approach 1 + 2:
  - Attribute-based approach can be used for screening to identify grid components to be modified to enhance resilience
  - Consequence-based approach can be used to analyze investment alternatives
  - Will be applied to a New Orleans case study

Principles of CONSEQUENCE-BASED Approach

Weather Conditions (e.g., trajectory, wind speeds, etc.)

↓

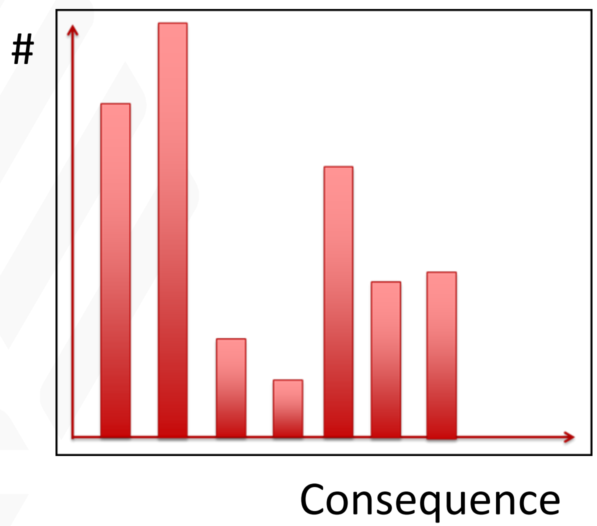
Effects of Weather (e.g., physical damage)

↓

Model of Grid Ops

↓

Histogram of Grid Consequences (e.g., Shed Load)



Principles of CONSEQUENCE-BASED Approach (cont.)

Uncertainty In Inputs

Weather Conditions (e.g., trajectory, wind speeds, etc.)

↓

Effects of Weather (e.g., physical damage)

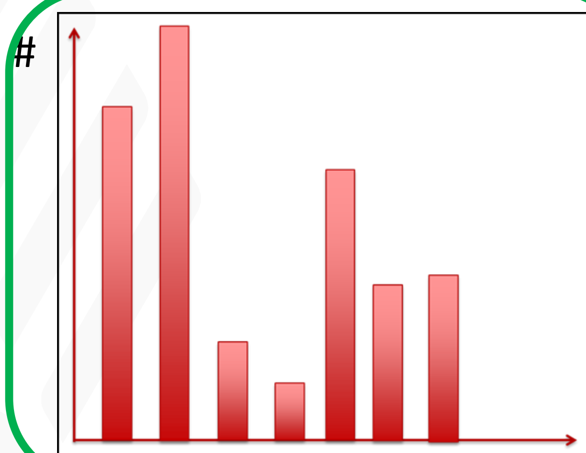
↓

Model of Grid Ops

↓

Histogram of Grid Consequences (e.g., Shed Load)

Uncertainty in Outputs



Histogram of consequences leads to resilience metrics

Exploring Investment Options on Consequences to Threats

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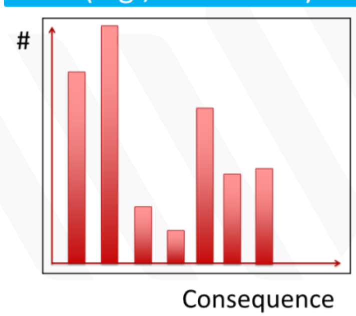
Baseline

Weather Conditions (e.g., trajectory, wind speeds, etc.)

Effects of Weather (e.g., physical damage)

Model of Grid Ops

Histogram of Grid Consequences (e.g., Shed Load)



With Mitigation

Weather Conditions (e.g., trajectory, wind speeds, etc.)

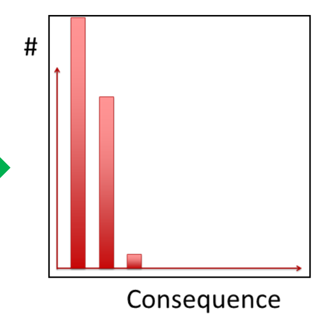
Effects of Weather (e.g., physical damage)

Effects of Investment Options

Model of Grid Ops

Histogram of Grid Consequences (e.g., Shed Load)

Change in histogram represents resilience improvement



Principles of ATTRIBUTE-BASED Approach

Resilience index is based on 4 sub-indices

Level 1
Level 2

- **Preparedness**
  - Awareness
  - Planning
- **Mitigation Measures**
  - Mitigating Construction
  - Utility Mitigation
  - Resources Mitigation Measures
- **Response Capabilities**
  - Onsite Capabilities
  - Offsite Capabilities
  - IMCC Characteristics
- **Recovery Mechanisms**
  - Restoration Agreements
  - Recovery Time

IMCC: incident and management control center

RI Structure - Preparedness

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Level 1 | Level 2 | Level 3

- **Preparedness**
  - **Awareness**
    - **Standards**
    - **New Communication and Notification Measures**
    - **Training/Exercises with First Responders**
    - **Extreme Weather Assessment**
    - **Information Sharing**
  - **Planning**
    - **New Planning Measures**
    - **Business Continuity Plan**
    - **Emergency Operation / Emergency Action Plan**
    - **Cyber Security Plan**
    - **Procurement Management**
    - **Preventing Maintenance**
    - **Extreme Weather Procedures**

Possible End Products: Dashboard for Utility

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- Resilience Measurement Index Dashboard (Notional)